Received June 8, 1769.

XXX. *A Letter from Mr.* Lane, *Apothecary, in* Alderſgate-ſtreet, *to the Honourable* Henry Cavendiſh, *F. R. S. on the Solubility of Iron in ſimple Water, by the Intervention of fixed Air.*

Alderſgate-ſtreet, June 5, 1769.

SIR,

Read Nov. 23, 1769.

THE various impregnations of mineral waters have always been very difficult to explain: and whoever has read the divers, and often contradictory reaſonings upon the ſubject, muſt clearly perceive, that there is ſtill room for diſcoveries in this part of natural hiſtory.

You, Sir, by your accounts of fixed air, and of Rathbone-place water, related in the laſt volume of Philoſophical Tranſactions, have obliged the public with many additional lights on this branch of knowledge; and, from your known accuracy, and diligent purſuits in moſt philoſophical inquiries, the learned world has great reaſon to hope for many other new and uſeful improvements. To your judgment therefore, I ſubmit the following experiments; which are intended to ſhew, that iron is ſoluble in ſimple water,

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by the intervention of fixed air; and thence, that it is very probable, many different chalybeate ſprings ſuſtain their metallic charge by this means only.

The ſolution of iron in mineral waters, eſpecially in ſuch as, by expoſure, readily loſe the property of ſtriking a purple colour with aſtringent vegetables, has uſually been attributed to ſome ſubtile gas, or volatile acid. Chymiſtry, however, does not diſcover any acid ſolvent for iron, but what has greater affinity with alcalies; and by means of which, therefore, this metal will be precipitated. Hence if any water appears, with a predominant alcali, which has alſo the power of tinging with galls, and, on being expoſed to the open air, lets fall the iron, and loſes that property; may we not conclude the metal to have been ſuſpended by ſome other medium?

This, for example, is plainly the caſe in German Spa water, which Dr. Brownrigg has proved to abound with fixed air. Your own very curious experiments, before cited, have clearly ſhewn, that calcarious earths may be ſuſpended in water by this principle of fixed air. And theſe have led me to examine, whether iron might not be diſſolved by the ſame natural means.

I would not, however, be ſuppoſed to deny, that iron is frequently found united with an acid. The fact is ſufficiently evinced in the pyrites and vitriolic earths. Nor can I doubt, but that theſe ſubſtances do largely contribute to the primary impregnation of waters, they being ſo readily ſoluble in them. But as an alcali, or abſorbent earth, is often found more than ſufficient to ſaturate the acid in mineral waters; this would effectually diſengage every

particle of iron diſſolved by an acid, unleſs the metal was ſupported by ſome other menſtruum.

My endeavours, therefore, to detect this ſolvent, by experiments, are what I now beg leave to lay before you, in the order I made them.

Experiment I.

A wide-mouthed bottle, containing half a pint of diſtilled water and ſixty grains of ſteel-filings, was ſuſpended forty-eight hours over ſome diſtillers melaſſes, in briſk fermentation; ſo as to receive the fixed air eſcaping from the fermenting liquor; the ſurface of which was ten inches below the mouth of the bottle. Immediately after its removal, the clear water was decanted from the filings and ochrous ſediment.

This liquor had a briſk and ferruginous taſte, with a flavour of the melaſſes. An infuſion of galls, or green tea, ſoon changed part of it to a colour like ink. The remainder, being expoſed to the open air, preſently became turbid, threw up a party-coloured pellicle, and depoſited a yellowiſh ſediment.

The water now retained but very little power of tinging with galls; and in a few days loſt this property entirely.

Experiment II.

Fourteen ounces of coarſe ſugar, diſſolved in ſeven pints of water, were mixed with half a pint of yeaſt, in a bottle capable of holding more than twice the above quantity. One end of a bent tube was luted into this veſſel, ſo that no air might eſcape but through the

the tube; the other end was looſely inſerted two inches within the mouth of another large bottle, charged with four hundred grains of iron filings, and ſixty ounces of diſtilled water. After remaining twelve hours in this ſituation, the ſugar working briſkly, an ounce phial was let down gently into the bottle, and filled. The water from the phial, with one drop of tincture of galls *, changed in a few minutes to a light roſy purple. The liquor being ſhaken, and another phial-full taken up ſoon after, one drop of the tincture gave a deeper colour than before. In an hour and half more, after being ſhaken again, the phial-full received a ſtill deeper purple, from the like quantity of tincture. The bottle continuing as before near five hours longer; when the quantity of fixed air from the fermenting liquor was ſuppoſed ſufficient to have ſaturated the water; the liquor appeared very turbid on being ſhaken; and, after ſtanding another hour, under the tube, to ſettle, the whole was filtered.

Thirty ounces of the clear liquor was poured into two Florence flaſks, and the remainder into phials, which were afterwards well corked. Two of theſe phials had their corks dipped into melted reſin, ſo as to cover the mouths of the bottles. Two others were encloſed with a paſte or lute.

Notwithſtanding the above precautions to prevent the eſcape of air, the liquors in each ſoon grew turbid, and by the next morning depoſited yellow ſediments.

* This tincture was made by infuſing half an ounce of powdered galls in eight ounces of proof ſpirit, for four days, without heat.

This water had a ſmart chalybeate taſte, ſomewhat reſembling Spa water; with a ſlight flavour of the fermenting liquor.

One drop of tincture of galls gave a roſy purple colour to a wine-pint of this water.

Syrup of violets turned it green *.

Soap leys, or even alcaline ſalts, either fixed or volatile in their natural ſtates, ſoon changed this liquor green, and rendered it turbid, whence a yellow ſediment enſued.

But neither of the alcaline ſalts, when previouſly ſaturated with fixed air, produced any perceptible alteration.

Nor did any viſible change happen on the addition of acids.

The thirty ounces of water, in the flaſks before mentioned, after being boiled twenty minutes, to expel the air, became very turbid, and let fall ſediments. The clear liquor being decanted, the remainder was paſſed through a filter, and, after drying, the paper appeared to have gained two grains and a quarter.

This ochrous reſiduum could not be again diſſolved in water, by means of fixed air; but was ſoluble in the vitriolic acid. The ſolution, diluted and filtered, received no colour from galls, until alcali was added to ſaturate the redundant acid; after which it ſtruck a purple, as in common ſolutions of iron.

* Simple diſtilled water, ſaturated with fixed air, by any means I have tried, makes no change in ſyrup of violets: and, when mixed with ſoap, does not curdle.

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The liquor, decanted after boiling, neither changed colour with galls, nor ſhewed any precipitation with lime-water.

Experiment III.

A common quart-bottle was half filled with diſtilled water, to which were added an hundred grains of ſteel-filings. To theſe was introduced, by means of the bent tube, as much fixed air, obtained from a ſolution of alcaline ſalt in the vitriolic acid, as was judged ſufficient to fill the bottle. The whole being then ſhaken, with my hand over its mouth, the bottle ſtuck like a cupping-glaſs. About the ſame quantity of air being again added, the bottle, after ſhaking, had leſs adheſion than before. On repeating this experiment, a third time, with freſh air, the adheſion was ſcarcely perceptible. And after the fourth trial, a ſmall portion of air was obſerved to iſſue from the bottle. The water now gave a deep colour with tincture of galls.

This experiment was repeated with fixed air from different combinations. As alſo by paſſing this air through a veſſel of pearl-aſh, to arreſt any acid which might eſcape from the effervеſcing mixtures. But the ſolutions of iron, in all the trials, appeared to be exactly ſimilar, except ſome trifling difference in taſte and ſmell.

Experiment IV.

A bottle, with the like quantity of ſteel-filings and diſtilled water as in Experiment the Firſt, remained

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in a room many weeks; yet although it was frequently ſhaken, and had an ochrous ſediment, it gave no colour with tincture of galls,

Experiment V.

A ſingle grain of iron in ſolution *, diluted with a pint of diſtilled water, changed to a deep blue purple, with the tincture of galls. Half a pint of the like mixture, expoſed many days in a wide-mouthed glaſs covered looſely with paper, let fall a ſlight precipitation; but its property of tinging with galls was not ſenſibly diminiſhed. The ſame quantity being boiled four or five minutes, in a Florence flaſk, became turbid, and depoſited a ſmall portion of an ochrous ſediment. The tincture of galls, nevertheleſs, gave as deep a colour to the clear liquor, as it would have done before boiling.

The foregoing experiments ſeem to prove, that iron remains quite unaffected by pure water, but may eaſily be diſſolved in it on the addition of fixed air; and that in whatſoever manner this air is generated, the event will appear the ſame. The laſt experiment ſhews, that where iron is ſuſpended in water, by an acid, neither expoſure nor boiling will deſtroy its property of tinging with galls; which is the reverſe of what we find to be the caſe with many ferruginous waters. Experiment the Second more particularly

* Iron-filings were diſſolved in diluted oil of vitriol to ſaturation; and, by experiment, one grain of the metal, with about two grains and a quarter of the acid, were found to be contained in ſixty-eight grains of the ſolution.

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teaches, that the iron, diſſolved in water by fixed air, is at leaſt equal in quantity to what is commonly aſcribed to moſt chalybeate ſprings: that this air, by which the metal is held in ſolution, is ſimilar to that elaſtic vapour, ſo often mentioned by writers on theſe ſubjects; which cannot be wholly retained by the cloſeſt corking, but, gradually eſcaping, ſuffers the ochrous matter to ſubſide. And that fixed air has greater affinity with alcalies than with iron, becauſe addition of alcaline ſubſtances, not ſaturated with fixed air, will diſengage the metal, while ſuch as are charged with this principle produce no alteration.

Theſe concluſions ſeemed to account for many particulars relating to medicated ſprings; but as all my trials had been made with iron in its metallic ſtate, which is rarely found in nature, it was neceſſary to repeat them upon this mineral in the ſtate of ore. I proceeded, therefore, to different experiments upon various ores; but did not find any of them to anſwer my expectation, except what is called iron ſand ore, which ſeems to contain a perfect iron.

This, at firſt, offered a material objection to my former inference. But, upon a little conſideration, it occurred, that waters, being firſt charged with pyritical matter, might afterwards have their acid neutralized with alcaline or calcarious ſubſtances, and the iron yet remain ſuſpended by air generated in the ſaturation. And I was the more ready to adopt this opinion, as it would explain, very naturally, the application of fixed air to this buſineſs of ſolution; which, I confeſs, had hitherto been to me ſomewhat difficult to account for. It was neceſſary, however, to examine the truth of this theory, by the

the teſt of experiment, which I did in the following manner.

Experiment VI.

To a pint of diſtilled water, mixed with one grain of iron diſſolved (as in Experiment the Fifth), were added forty grains of ſoap leys.

And to two ounces of lime-water, diluted with fourteen ounces of diſtilled water, was added a grain of iron in ſolution.

In both caſes the point of ſaturation was intended. The two mixtures inſtantly turned green, grew turbid, and let fall ſediments of the ſame colour. The liquors, being filtered, gave no tinge with tincture of galls.

Experiment VII.

A quart of water was mixed with two grains of iron, as before.

To one moiety, three grains of ſalt of tartar in ſolution was inſtilled. It firſt appeared green, ſoon changed yellow, and gave an orange-coloured precipitate.

To another portion two grains of powdered chalk being added, it preſently became ſtraw-coloured, and after continuing nine hours in a well-corked phial, was yet turbid, with a yellow ſediment.

The waters being both filtered, part of each changed to a purple, with tincture of galls. The remainder being boiled, a farther precipitation enſued, and the clear liquor no longer produced any alteration with galls.

This experiment being repeated with magneſia, and with the earth of alum, ſhewed no ſenſible difference.

The quantity of iron, left diſſolved in the liquor, was found in proportion to the volume of air generated during the ſaturation.

If the quantity of alcali or abſorbent earth was inſufficient to ſaturate the acid, part of the iron would remain in the water after boiling. All which were diſcoverable by the tincture of galls.

Experiment VIII.

To a pint of diſtilled water, being ſaturated with fixed air, and containing four grains of chalk, was added a grain of iron in ſolution; the mixture continued pellucid.

Another grain of diſſolved iron was diluted with a like quantity of water, previouſly ſaturated with air from a ſolution of pearl-aſh in vitriolic acid: eight grains of ſalt of tartar, cryſtallized with fixed air, and diſſolved, were added to this mixture: a ſlight degree of cloudineſs enſued, but diſappeared on ſhaking; after which the liquor much reſembled Spa-water; only it taſted ſtronger of the iron. The quantity of chalk, and alcaline ſalt, in this experiment, was more than ſufficient to neutralize the acid.

Both the above mixtures, on expoſure, became turbid, threw up pellicles, depoſited ferruginous ſediments, and loſt their power of ſtriking a purple with galls.

Solutions of iron, and of its ores, in the marine and nitrous acids, as alſo pyrites diſſolved in rain-water, were ſubſtituted, by turns, inſtead of the original iron in vitriolic acid; and they all gave a purple colour with tincture of galls.

The trials were repeated with lime-ſtone, marble, iſland cryſtal, oſteocolla, and magneſia, in lieu of chalk; and with volatile and mineral alcali, replete with air, in the room of ſalt of tartar; but no material difference was obſerved.

The ſucceſs of theſe experiments compleatly anſwered my expectations. They ſatisfied me, that any acid holding iron diſſolved, and diluted with water, might not only be neutralized, but the water charged with an exceſs of alcaline or earthy matter, without precipitating the metal; and that the ſolvent, in theſe caſes, could be no other than *Fixed Air*. Since the iron remained in ſolution, only where this principle originally abounded in the water, or was afterwards generated in the ſaturation.

Thus much being determined, it ſeemed eaſy to apply the diſcovery to the more perfect analyzation of ſome waters; and to the re-production of others, by art, which ſhould exactly reſemble thoſe of natural medicated ſprings. This is a taſk I ſhould probably have undertaken at leiſure; had I not been informed, that Dr. Watſon, junior, by whoſe converſation my thoughts were firſt led to the ſubject, is already engaged in ſomething of this ſort. This gentleman ſaw many of the foregoing experiments repeated; and, as he is ſince gone to the German Spa, I dare ſay, his abilities and application will ſufficiently improve the

the opportunity: I ſhall gladly, therefore, wait the reſult of his enquiries.

To conclude then: It appears to me highly probable, that fixed air is generally neceſſary to the impregnation of mineral ſprings. That by the right knowledge of this principle, we may now ſolve moſt difficulties that have ariſen on this ſubject; and very poſſibly be able, hereafter, to imitate nature, in the formation of medicated waters. Whether my concluſions are well founded, I with pleaſure refer to your candid deciſion. And am,

SIR,

with great reſpect,

Your much obliged,

humble ſervant,

T. Lane.